Contribution of neighbourhood socioeconomic status and physical activity resources to physical activity among women

Rebecca E Lee, Catherine Cubbin, Marilyn Winkleby

J Epidemiol Community Health 2007;**61**:882–890. doi: 10.1136/jech.2006.054098

See end of article for authors' affiliations

Correspondence to: Dr Rebecca E Lee, Health and Human Performance, University of Houston, Garrison Gym 104E, 3855 Holman Road, Houston, TX 77204 USA; releephd@yahoo.com

Accepted 4 January 2007

Introduction: Residence in a deprived neighbourhood is associated with lower rates of physical activity. Little is known about the manifestation of deprivation that mediates this relationship. This study aimed to investigate whether access to physical activity resources mediated the relationship between neighbourhood socioeconomic status and physical activity among women.

Method: Individual data from women participating in the Stanford Heart Disease Prevention Program (1979–90) were linked to census and archival data from existing records. Multilevel regression models were examined for energy expenditure and moderate and vigorous physical activity as reported in physical activity recalls.

Results: After accounting for individual-level socioeconomic status, women who lived in lower-socioeconomic status neighbourhoods reported greater energy expenditure, but undertook less moderate physical activity, than women in moderate-socioeconomic status neighbourhoods. In contrast, women living in higher-socioeconomic status neighbourhoods reported more vigorous physical activity than women in moderate-socioeconomic status neighbourhoods. Although availability of physical activity resources did not appear to mediate any neighbourhood socioeconomic status associations, several significant interactions emerged, suggesting that women with low income or who live in lower-socioeconomic status neighbourhoods may differentially benefit from greater physical activity resource availability.

Discussion: Although we found expected relationships between residence in a lower-socioeconomic status neighbourhood and undertaking less moderate or vigorous physical activity among women, we also found that these same women reported greater overall energy expenditure, perhaps as a result of greater work or travel demands. Greater availability of physical activity resources nearby appears to differentially benefit women living in lower-socioeconomic status neighbourhoods and low-income women, having implications for policy-making and planning.

Neighbourhood socioeconomic status (SES) is associated with residents' physical activity (PA),[1 2] but little is known about neighbourhood factors that account for the association. Understanding neighbourhood factors that influence PA may help explain the consistently low rates of PA in the US,[3] particularly among persons residing in low-SES neighbourhoods. Women may be particularly vulnerable to lower-SES neighbourhood environments[4–7] and lower rates of PA.[3 8] Evidence suggests a need for research focused specifically on women to understand these phenomena.

Epidemiological studies have typically focused on aggregate, population-level variables to measure neighbourhood SES or deprivation (e.g. census-based measures of income or educational attainment). For example, residence in neighbourhoods with lower SES has been associated with low levels of PA.[1] A disadvantage of this strategy is that it is difficult to pinpoint the topographical or social manifestation of deprivation that contributes to physical inactivity. Deprived neighbourhoods have higher crime rates and reduced collective efficacy,[9 10] and fewer goods and services available.[11 12] PA resources[13 15] may vary by the SES of the neighbourhood, with more deprived neighbourhoods having fewer PA resources in most US studies, although one study in Australia found that public open spaces were more common in more deprived neighbourhoods.[16] Neighbourhood factors may be especially influential among women, who may rely more on their neighbourhood for resources as a result of child rearing and other domestic responsibilities.[17] Women's social connections and participation in local organisations may be inhibited more than men's in deprived neighbourhoods, because there may be fewer opportunities,[18] potentially contributing to social isolation.[17]

Initial investigations have typically employed resident self-reports of neighbourhoods. Residents who report their neighbourhoods to be less safe report lower levels of PA,[19 20] and self-report of convenient PA facilities has been correlated with greater PA.[21–26] As women may have higher exposure to neighbourhood environments, they may have attitudes and experiences that in turn influence their health behaviours.[27] Although self-reported information may be reliable,[28] it is unclear whether resident reports validly represent the neighbourhood as they may be coloured by greater experience with one's neighbourhood. The correlation between greater PA and reports of supportive neighbourhoods may simply be a result of greater time in the neighbourhood during PA.[5 25 29 30] It is important to have accurate and reliable neighbourhood data to know where policy and intervention efforts should be targeted to influence the majority of the population, not just those who are already physically active.

Few studies have investigated the relationship between neighbourhood factors and residents' PA using objective evaluations relying on topographical features of neighbourhoods or municipal records, such as planning databases or archival records (e.g. telephone books). Greater density of PA resources has been associated with resident exercise,[31] and closer measured distance to PA resources such as a community trail is associated with greater use.[26] Residence near a seashore, or perhaps any aesthetically pleasing outdoor space, is associated with more PA.[32] Studies like these suggest that physical elements in neighbourhoods are associated with PA.

The goal of this study was to investigate the relationship between neighbourhood SES and individual PA, and then to determine whether relationships were mediated by available PA resources among women who participated in the Stanford Heart Disease Prevention Program.

METHODS

Data

The analysis was based on multiple sources of linked data: the Stanford Heart Disease Prevention Program (SHDPP), 1979–90, contained respondent data from surveys, laboratory measures and residential addresses. The SHDPP was a five-city, 6-year field trial, begun after the baseline survey (1979–10), and was designed to test whether a comprehensive programme of community organisation and health education produced favourable changes in the risk of cardiovascular disease.[33] The SHDPP drew participants from a total of 82 neighbourhoods across two treatment (Monterey, Salinas) and two control (Modesto, San Luis Obispo) cities in northern California, ranging in population size from 35 000 to 145 000 residents (a fifth city, Santa Maria, was followed for morbidity/mortality surveillance only and is not included in the analysis). Independent cross-sectional surveys of randomly selected households were conducted. All people aged 12–74 years were eligible to participate and were invited to attend study centres located in each city, where they completed surveys, had risk factors assessed by nurses and underwent laboratory tests.[33–35] Response rates for the five surveys ranged from 56% to 69%. Respondents were more likely than non-respondents to speak English, be more educated and be overweight (women only), and were less likely to smoke. The magnitude of these differences was modest, suggesting little response bias.[36 37] Few significant intervention-related changes in risk factors were found; thus, all cities were combined for this analysis.[36 38]

The sample for this study included one woman per household, aged 25–74, interviewed during survey 1 (1979–80), 4 (1984–85) and 5 (1989–90), when information on PA was collected (n = 2672). Nearly 80% had lived in their ''community'' for five years or longer. On average, 12 (median = 9) women participated per neighbourhood (range 1–56), calculated separately by survey. All research was approved by the appropriate ethics committee at Stanford University and conforms to the principles of the Declaration of Helsinki.

The SHDPP respondent data were linked via residential addresses to census-defined neighbourhoods. In order to characterise neighbourhoods using census data, we chose a priori to rely upon census-defined boundaries (tracts and/or block groups) that have been used as proxies for geographically based neighbourhoods.[4 5 29 39–41] We compared the census-defined boundaries with archival paper city maps from the time of the surveys, and determined that the neighbourhood boundaries corresponded well with single census tracts or block groups. When there was a difference (n = 12), we used a combination of tracts or block groups to better represent neighbourhood boundaries, based on guidance from city planners, neighbourhood maps in the cities and comparison of boundaries in 1980 and 1990. Eighty-two neighbourhoods with the same boundaries for each survey were defined. We tested the accuracy of the geocodes in two ways.[42] Using the government geocoding website as the ''gold standard'' (http://www.ffiec.gov/geocode/default.htm), we found that 95–98% of a random sample of 173 participant records geocoded to the same 1990 census tract geocode as the geocoding service that we used. Second, we conducted a site visit in two of the cities with census tract maps from the Bureau of the Census to determine whether the geocode corresponded to the correct census tract in which the address was located, and found high agreement (20 out of 21 addresses were located in the same census tract indicated by the geocoding service). Participants with addresses outside the cities (n = 84, or 1.0%) and participants whose addresses were not able to be geocoded (n = 138, or 1.6%) were excluded.

To describe the availability of PA resources, the addresses of gyms, health clubs, health centres and exercise programmes (''gyms'') were collected from the business listing of telephone books for the survey years (1979–80, 1984–85, 1989–90). All businesses received a free listing in the telephone books, and business listings were considered ''highly complete'' when the investigators made inquiries to telephone book company employees who oversaw listings. Addresses of public parks were obtained from each city's parks and recreation department. About 98% of the gyms (87 out of 89) and 75% (132 out of 177) of the parks were successfully geocoded to the 82 defined neighbourhoods. The lower success rate for geocoding parks resulted from street addresses that were not complete (e.g. street name given without a number). Variables measuring distance and density were calculated.

Independent variables at the individual level

The independent variables at the individual level were age, race/ethnicity, marital status, annual household income as a percentage of the federal poverty level (0–200%, 201–400%, 401–600%, 601+%) and educational attainment (< 12, 12, 13–15, 16+ years). The Spearman correlation between income and education was 0.35. Treatment versus control city and time of survey were included as control variables.

Independent variables at the neighbourhood level

To characterise neighbourhood-level SES, we conducted a principal component analysis with 11 SES-related variables from the 1980 US census and identified the following five variables that loaded high on the first component and explained 72% of the total variance: percentage aged 25 and over with less than high school education; median annual family income; percentage blue collar workers; percentage unemployed among the civilian labour force; and median housing value. Correlations among the five variables ranged from 0.50 to 0.85. When constructing the index, 1980 census data were used for the first survey (1979–80) and 1990 census data were used for the fifth survey (1989–90). For survey 4 (1985–86), the index was estimated using linear interpolation. Each of the five variables were standardised separately by city and survey and summed with equal weights for each of the 82 neighbourhoods in each survey. The index was then divided into three groups – lower SES (bottom 25%), moderate SES (middle 50%) and higher SES (top 25%) – separately by city and survey. The number of neighbourhoods differed by city, ranging from 7 to 33.

To characterise PA resources at the neighbourhood level, we examined (1) the count of gyms (number of gyms in each neighbourhood), (2) the count of parks (number of parks in each neighbourhood), (3) the density of gyms (number of gyms in each neighbourhood/square mileage of each neighbourhood) and (4) the density of parks (number of parks/square mileage). To characterise PA resources at the individual level, we also examined (5) the closest distance in miles from the participant's home address to a gym or a park and (6) a count of gyms and parks located within a half-mile radius (''buffer zone'') of a participant's home.[43]

Dependent variables

Three variables measuring PA were examined. Daily energy expenditure (kilocalories per kilogram of body weight per day) was defined based on participant estimates of time spent over

the last 7 days in sleep and in moderate (e.g. walking at a brisk pace), hard (e.g. scrubbing floors) and very hard (e.g. jogging or swimming) activity; light activity was calculated as the remaining time after accounting for time spent in the other activities. Activities were classified by their energy requirement and expressed in terms of the ratio of the work metabolic rate to the resting metabolic rate, expressed as metabolic equivalents.[44–46] Moderate activity was defined as a count of up to four activities usually done (climbing stairs instead of taking the lift, walking instead of driving a short distance, parking away from destination in order to walk further, walking on lunch break or after dinner). Vigorous activity was defined as performing any of the following activities regularly for the past 3 months (jog at least 10 miles per week, play strenuous racquet or other sports at least 5 hours per week, ride a bicycle at least 50 miles per week or swim at least 2 miles per week).

Analysis

For the primary statistical analyses, a series of multilevel logistic or linear regression models with random intercepts were examined for each dependent variable, using the SAS GLIMMIX macro or the MIXED procedure (SAS Institute, Cary, NC, USA).[47] For each dependent variable, we calculated a null model and a baseline model with only neighbourhood SES to calculate the percentage of variation in the neighbourhood means explained by neighbourhood SES (by subtracting the between-neighbourhood variance in the baseline model with neighbourhood SES from the total between-neighbourhood variance obtained in the null model (null models not shown) and then dividing by the total). Next, age, race/ethnicity, marital status, income, education, an indicator variable for treatment vs. control city and survey time were added to create the full model. We then added each of the variables measuring the availability of PA resources (parks and gyms) one at a time as continuous measures to create models that included geographical information systems (GIS) data to determine whether neighbourhood SES influences were mediated by park and gym availability. We also tested for interactions between individual income (and education) and neighbourhood SES, income (and education) and each of the variables measuring the availability of PA resources (parks and gyms), and neighbourhood SES and each of the variables measuring the availability of PA resources.

RESULTS

Over half the women were under age 45, most were white non-Hispanic, and nearly two-thirds were married at the time of survey (table 1). Although 17% of the women had not completed high school, over half had attended college for at least some period. Nearly two-fifths of the women had incomes that were over 400% of the federal poverty level. Women were about equally distributed by city and survey; however, about twice as many women lived in higher-SES neighbourhoods as in lower-SES neighbourhoods.

On average, women used 35.7 kcal/kg of energy per day. Levels were slightly higher for women who were younger, Hispanic, never married, of lower SES, living in Salinas, interviewed during survey 4 and living in the lower-SES neighbourhoods. Larger differences were found for moderate PA. Overall, women reported 1.7 moderate activities out of a total of 4 possible. Higher counts were reported for women who were younger, white non-Hispanic, never married, of higher SES, living in Monterey or San Luis Obispo, interviewed during survey 4 and living in the higher-SES neighbourhoods. Vigorous PA showed the largest differences. Seven per cent of women in the sample reported undertaking at least one of the vigorous activities. In general, much higher percentages were reported for women who were younger, ''other'' race/ethnicity, never married, of higher SES, living in Monterey or San Luis Obispo, interviewed during survey 5 and living in the higher-SES neighbourhoods.

On every measure of PA resources (table 2), availability of gyms and parks was greater in lower-SES neighbourhoods than in higher-SES neighbourhoods, with the exception of distance, with the average distance to a gym or a park being one-tenth of a mile less in higher-SES neighbourhoods than in lower-SES neighbourhoods. Differences were statistically significant except in the case of gyms per square mile. Similar patterns were observed when we examined the data stratified by individual-level SES.

Table 3 presents the results from a series of multilevel regression models for daily energy expenditure. The between-neighbourhood variance was statistically significant ($p<0.0001$), and 9% of the between-neighbourhood variance in daily energy expenditure was explained by neighbourhood SES. In the baseline model, women who lived in lower-SES neighbourhoods had higher energy expenditure than those in moderate-SES neighbourhoods. That association remained significant in the full model and in each GIS model (only the model including gym density is shown; other model results are available upon request). Although none of the PA resource measures were significant when they were added to the full model separately, we found a significant interaction between individual income and gym density (figure 1A). As gym density increased, low-income women reported greater energy expenditure (35.8 kcal/kg/day in the highest density neighbourhoods) than high-income women, who reported less energy expenditure (34.8 kcal/kg/day in the highest density neighbourhoods). For a 150-pound woman (~68 kg) this would translate into an additional 68 calories per day expended. Aside from age and a survey effect, no other statistically significant associations were found with gym density or any of the other PA resource availability measures.

Table 4 presents a similar series of models for moderate PA. The between-neighbourhood variance was statistically significant ($p<0.0001$), and 8% of the between-neighbourhood variance in moderate PA was explained by neighbourhood SES. Women living in lower-SES neighbourhoods were more likely to report undertaking fewer moderate activities than women in moderate-SES neighbourhoods. That association was no longer statistically significant in the full model. Hispanic women and other racial/ethnic groups reported fewer moderate activities than white women, and younger age and higher income or education was associated with more moderate activities. None of the PA resource measures were significant when they were added to the full model separately (see GIS model). However, two significant interactions were found (figure 1B and C): neighbourhood SES with gym density and neighbourhood SES with parks. Women who lived in higher-SES neighbourhoods reported fewer moderate activities as gym density or parks increased, while women who lived in lower-SES neighbourhoods reported more moderate activities as gym density or parks increased.

Table 5 presents the logistic regression results for vigorous PA. The between-neighbourhood variance was statistically significant ($p = 0.0003$); and, although none of the between-neighbourhood variance in vigorous activity was explained by neighbourhood SES, women living in higher-SES neighbourhoods had about 50% higher odds of reporting vigorous PA than their counterparts living in moderate-SES neighbourhoods. However, in the full model, those odds were no longer statistically significant. Younger women and women with more education were more likely to report vigorous PA than older women and women with less education. None of the PA resource measures were significant when they were added to

Table 1 Sample characteristics and prevalences of physical activity among women in the Stanford Heart Disease Prevention Program, 1979–90

	Distribution, n (%)	Daily energy expenditure (mean kcal/kg/day)	Moderate physical activity (mean count)	Vigorous physical activity (% yes)
Overall	2672 (100.0)	35.7	1.7 range 1–4	7.0
Individual factors				
Age group (years)				
25–44	1417 (53.0)	36.4	1.8	10.4
45–64	912 (34.1)	35.3	1.7	3.8
65–74	343 (12.8)	34.1	1.6	1.8
Race/ethnicity				
Hispanic	308 (11.5)	36.7	1.3	6.2
White, non-Hispanic	2238 (83.8)	35.6	1.8	7.1
Other race/ethnicity	126 (4.7)	35.5	1.4	7.9
Marital status				
Married	1738 (65.0)	35.7	1.7	6.7
Never married	219 (8.2)	36.1	2.0	11.9
Previously married	715 (26.8)	35.6	1.7	6.3
Education				
< High school	458 (17.2)	36.1	1.2	2.6
High school graduate	817 (30.6)	35.7	1.6	4.4
Some college	1080 (40.4)	35.6	1.9	8.8
College graduate	315 (11.8)	35.5	2.1	14.3
Income				
0–200%	610 (24.0)	35.8	1.6	5.3
201–400%	972 (38.3)	36.0	1.7	6.7
401–600%	540 (21.3)	35.4	1.9	8.3
601+%	417 (16.4)	35.3	2.0	9.1
Design factors				
City				
Monterey	715 (26.8)	35.3	2.0	9.1
Salinas	700 (26.2)	36.2	1.5	5.3
Modesto	719 (26.9)	35.9	1.5	4.7
San Luis Obispo	538 (20.1)	35.4	2.0	9.7
Survey				
1 (1979–80)	837 (31.3)	35.7	1.7	6.3
4 (1985–86)	910 (34.1)	36.6	1.9	6.9
5 (1989–90)	925 (34.6)	34.8	1.6	7.8
Neighbourhood socioeconomic status				
Low (25%)	463 (17.3)	36.6	1.6	6.7
Moderate (50)	1349 (50.5)	35.6	1.7	6.2
High (25%)	860 (32.2)	35.4	1.8	8.5

the full model separately (see GIS model). No statistically significant interaction effects were found.

Conclusions were unchanged when we repeated the models with higher neighbourhood SES as the reference group.

DISCUSSION

Women who live in lower-SES neighbourhoods reported greater energy expenditure, but undertook fewer moderate physical activities, than women in moderate-SES neighbourhoods. In contrast, women living in higher-SES neighbourhoods reported more vigorous activity than women in moderate-SES neighbourhoods. Although availability of PA resources did not appear to mediate any neighbourhood SES associations, several significant interactions emerged, suggesting that women with low income or who live in lower-SES neighbourhoods may benefit from greater PA resource availability.

Table 2 Physical activity resources* by neighbourhood-level socioeconomic status (SES)

	Neighbourhood-level SES			
	Lower	Moderate	Higher	p Value
Gyms per neighbourhood	2.1	0.4	0.8	< 0.0001
Parks per neighbourhood	2.5	1.9	1.8	< 0.0001
Gyms per square mile	0.7	0.4	0.6	NS
Parks per square mile	1.9	2.2	1.5	< 0.0001
Closest distance to gym or park	0.3	0.3	0.4	< 0.0001
Gyms and/or parks in buffer zone	2.0	1.5	1.5	< 0.0001

*All values are mean counts, except for closest distance, which is measured in mean miles. NS, not significant.

Women who reside in lower-SES neighbourhoods reported greater energy expenditure but less moderate and vigorous PA, suggesting that these women are expending calories in activities that do not fit traditional definitions of exercise (i.e. structured, planned PA undertaken to enhance fitness). Women who reside in lower-SES neighbourhoods may have more opportunities for energy expenditure from daily lifestyle activities, such as work or travel, that may not have been detected by the instruments used in this investigation.[48] People in blue-collar jobs or who use public transport for travel report greater energy expenditure than people in white-collar jobs or who drive private vehicles.[49] Greater daily energy expenditure may also be a function of less time spent sleeping, perhaps as a result of working more hours to make ends meet.

Few previous studies have investigated neighbourhood associations with PA, and most have relied on measurement

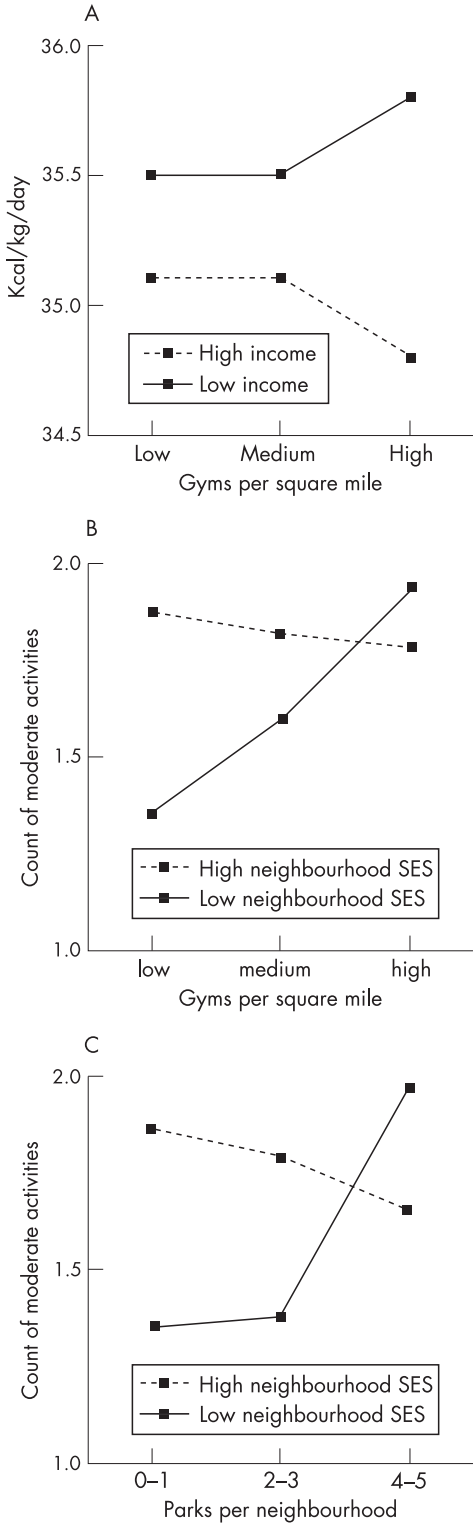

Figure 1 (A) Gyms per square mile: interaction between gym density and income. (B) Gyms per square mile: interaction between gym density and neighbourhood SES. (C) Parks per neighbourhood: interaction between parks and neighbourhood SES.

instruments that detected solely leisure-time exercise types of PA.[1 2 39] Taken together with the current findings, it is evident that there is a need to use more detailed assessment of PA that includes information on the nature and type of PA done across a variety of domains. This may be especially important in investigations that seek to understand socioeconomic and racial or ethnic disparities in PA and associated health-compromising conditions. Although monitoring leisure-time PA is important, there is a critical need for future studies to operationalise PA in a manner that is not based on the activities undertaken primarily by middle- and upper-SES women who have more time and resources for leisure-time PA. This is especially important given the increasing diversity of women and the large numbers of women in the workforce, many of whom may be the primary breadwinners in their families.

In contrast to the findings of other studies,[14 50] availability of PA resources was greater in lower-SES neighbourhoods than in higher-SES neighbourhoods. The distribution of PA resources may be driven by municipal factors such as the date of urban design[43] or how PA resources are defined. The three significant interactions suggested that women who live in lower-SES circumstances, at the individual or neighbourhood level, benefit from having PA resources available. Having more PA resources (gyms or parks in this study) may suggest more opportunities for PA either from using the resource itself or from other elements of the neighbourhood nearby the resource. Greater density of gyms and parks may suggest greater availability of goods and services in general, and that alone has been associated with greater PA.[51 52] Although the energy expenditure suggested by living in a neighbourhood with more PA resources is relatively small, it has large implications. Expending an additional 68 kcal/day would, for a woman weighing 150 pounds (68 kg), translate to about 1 pound (0.4 kg) lost, or not gained, in a year. From a lifespan perspective this small annual amount could make a large difference in quality of life in older adulthood. Policies that enhance access to PA resources and urban design may have the capacity to influence the health of generations to come. Future studies are needed that enhance the understanding of how neighbourhoods can support physically active lifestyles by providing PA opportunities via neighbourhood PA resources, design and transport provision.

The relationship between PA and available resources is complex. The relationship found between higher neighbourhood SES and greater vigorous PA is consistent with previous findings.[1 39 53] However, unlike the relationship of overall energy expenditure and moderate PA to PA resource availability, vigorous PA appears to be unrelated to PA resource availability in our study. For vigorous PA, perhaps quality, safety and cost of PA resources may be more important factors than physical access to the resource.[43 54] Previous studies have found that numbers and types of PA resources are similar in higher- and lower-SES neighbourhoods, but that the PA resources in the high-SES neighbourhoods are of much higher quality.[43] Unpublished investigations of those same data found that residents in neighbourhoods with PA resources that had fewer incivilities (eg litter, graffiti) and higher quality reported more PA. Others have reported that the size and attractiveness of public open spaces are determinants of PA among residents.[16]

The neighbourhood SES associations were no longer statistically significant in the full model of moderate or vigorous PA. However, it is important to keep in mind that individual-level income and education, as well as other sociodemographic factors, could be on the pathway between neighbourhood SES and the dependent variables (i.e. neighbourhoods may partially determine one's attainment of income through educational and employment opportunities); thus, the full models may be overcontrolling for mediating effects. The ''true'' neighbourhood SES effect may perhaps best be considered as lying somewhere between the baseline (unadjusted) model and the full model association.[55] In short, because the neighbourhood SES association is no longer significant in the full model does not necessarily mean that neighbourhood SES has no relationship to PA.

Table 3 Mean differences, with 95% confidence intervals (CIs), in daily energy expenditure among women in the Stanford Heart Disease Prevention Program

	Daily energy expenditure (kcal/kg/day)		
	Baseline model: mean difference (95% CI)	**Full model: mean difference (95% CI)**	**GIS model: mean difference (95% CI)**
Age (per year)		–0.001*** (–0.002 to –0.001)	–0.001*** (–0.002 to –0.001)
Race/ethnicity			
Hispanic		0.012 (–0.005 to 0.028)	0.012 (–0.004 to 0.027)
Other race/ethnicity		0.008 (–0.014 to 0.030)	0.008 (–0.011 to 0.031)
White, non-Hispanic		1.00	1.00
Marital status			
Never married		0.005 (–0.012 to 0.023)	0.006 (–0.013 to 0.021)
Previously married		0.003 (–0.007 to 0.014)	0.003 (–0.008 to 0.013)
Married		1.00	1.00
Income (per unit increase, range 1–4)		0.002 (–0.003 to 0.007)	0.002 (–0.009 to 0.003)
Education (per unit increase, range 1–4)		–0.004 (–0.010 to 0.002)	–0.004
Treatment vs. control city		–0.002 (–0.013 to 0.009)	–0.002
Survey			
1 (1979–80)		1.00	1.00
4 (1985–86)		0.018**(0.005 to 0.031)	0.018** (0.008 to 0.035)
5 (1989–90)		–0.025** (–0.038 to –0.012)	–0.025** (–0.037 to –0.011)
Neighbourhood SES			
Lower	0.025** (0.008, 0.041)	0.018** (0.003 to 0.034)	0.018* (0.004 to 0.035)
Moderate	1.00	1.00	1.00
Higher	–0.004 (–0.017, 0.010)	–0.002 (–0.014 to 0.010)	–0.002 (–0.012 to 0.013)
Gyms per square mile			–0.000 (–0.005 to 0.005)

Between-neighbourhood variance: 0.000822.
p value: p<0.0001
% explained by neighbourhood SES: 9%
*p<0.05; **p<0.01; ***p<0.001.
Note. Although models were run for each of the variables measuring the availability of PA resources (parks and gyms), only gyms per square mile is presented as a result of space constraints.

Table 4 Mean differences, and 95% confidence intervals (CIs), in moderate activity among women in the Stanford Heart Disease Prevention Program

	Vigorous activity		
	Baseline model: mean difference (95% CI)	**Full model: mean difference (95% CI)**	**GIS model: mean difference (95% CI)**
Age (per year)		–0.007*** (–0.010 to –0.003	–0.007*** (–0.010 to –0.003)
Race/ethnicity			
Hispanic		–0.200* (–0.366 to –0.034)	–0.197* (–0.363 to –0.031)
Other race/ethnicity		–0.235* (–0.462 to –0.009)	–0.234* (–0.460 to –0.008)
White, non-Hispanic		1.00	1.00
Marital status			
Never married		0.088 (–0.088 to 0.265)	0.087 (–0.090 to 0.263)
Previously married		0.064 (–0.047 to 0.174)	0.064 (–0.047 to 0.174)
Married		1.00	1.00
Income (per unit increase, range 1–4)		0.076** (0.024 to 0.127)	0.076** (0.024 to 0.127)
Education (per unit increase, range 1–4)		0.171*** (0.112 to 0.230)	0.170*** (0.111 to 0.229)
Treatment vs. control city		0.141* (0.020 to 0.261)	0.141* (0.019 to 0.262)
Survey			
1 (1979–80)		1.00	1.00
4 (1985–86)		0.096 (–0.248 to 0.046)	0.091 (–0.058 to 0.239)
5 (1989–90)		–0.101 (–0.052 to 0.243)	–0.109 (–0.257 to 0.040)
Neighbourhood SES			
Lower	–0.206* (–0.389 to –0.023)	–0.039 (–0.213 to 0.134)	–0.043 (–0.218 to 0.131)
Moderate	1.00	1.00	1.00
Higher	0.106 (–0.044 to 0.256)	–0.009 (–0.045 to 0.128)	0.003 (–0.135 to 0.140)
Gyms per square mile			0.021 (–0.037 to 0.079)

Between-neighbourhood variance: 0.1166
p value: p<0.0001
% explained by neighbourhood SES: 8%
*p<0.05; **p<0.01; ***p<0.001.
Note. Although models were run for each of the variables measuring the availability of PA resources (parks and gyms), only gyms per square mile is presented as a result of space constraints.

Table 5 Odds ratios and 95% confidence intervals (CIs) for vigorous activity among women in the Stanford Heart Disease Prevention Program

	Vigorous activity		
	Baseline model: odds ratio (95% CI)	Full model: odds ratio (95% CI)	GIS model: odds ratio (95% CI)
Age (per year)		0.95*** (0.94 to 0.97)	0.95*** (0.94 to 0.97)
Race/ethnicity			
Hispanic		1.34 (0.81 to 2.23)	1.33 (0.80 to 2.21)
Other race/ethnicity		1.28 (0.67 to 2.43)	1.27 (0.67 to 2.41)
White, non-Hispanic		1.00	1.00
Marital status			
Never married		1.14 (0.72 to 1.79)	1.14 (0.73 to 1.80)
Previously married		1.22 (0.86 to 1.74)	1.22 (0.86 to 1.74)
Married		1.00	1.00
Income (per unit increase, range 1–4)		1.14 (0.98 to 1.33)	1.14 (0.98 to 1.33)
Education (per unit increase, range 1–4)		1.63*** (1.34 to 1.98)	1.64*** (1.24 to 11.29)
Treatment vs. control city		1.09 (0.75 to 1.58)	1.10 (0.76 to 1.59)
Survey			
1 (1979–80)		1.00	
4 (1985–86)		1.07 (0.68 to 1.70)	1.10 (0.69 to 1.74)
5 (1989–90)		1.130.72 to 1.78)	1.16 (0.74 to 1.83)
Neighbourhood SES			
Lower	1.01 (0.60, 1.68)	1.18 (0.67 to 2.06)	1.21 (0.69 to 2.12)
Moderate	1.00	1.00	1.00
Higher	1.53* (1.04, 2.26)	1.45 (0.97 to 2.17)	1.49 (0.99 to 2.23)
Gyms per square mile			0.92 (0.76 to 1.10)

*p<0.05; **p<0.01; ***p<0.001.
Note. Although models were run for each of the variables measuring the availability of PA resources (parks and gyms), only gyms per square mile is presented because of space constraints.

Neighbourhood SES is associated with PA, although the relationships are complex and warrant greater investigation. Although state of the art at the time, the PA measurement in this study is a limitation by today's standards. The measure of energy expenditure is not detailed enough to determine precisely where the calories are used. This study relied on a composite, indicator variable to measure moderate PA. Thus, if participants did the activities assessed by the questions, then it is assumed that they probably also engaged in other types of moderate PA regularly, because they are more physically active across a much wider domain of moderate intensity physical activities. Although having a gym or park nearby may not directly influence whether a person routinely takes the stairs or parks further away from the store, it may influence one's ability to get the total recommended amount of PA every day. The four questions measuring moderate PA may simply be an indicator of the types of moderate PA that a person might do. Future investigations should include objective measures of PA and detailed descriptions of PA resources.[43] Investigations that include more detailed measures of the physical environment may help to define which features of PA resources, if any, contribute to PA, and how these resource features can be integrated into lower-SES neighbourhoods, where the need to increase PA is greatest. Despite these limitations, the findings are robust and consistent with previous findings, suggesting merit in the use of these data to investigate the vexing questions surrounding widespread levels of insufficient PA.

The strengths of the study include the careful assessment of neighbourhood boundaries, validation of geocodes and low

What this paper adds

Neighbourhood socioeconomic status (SES) influences residents' physical activity (PA) levels, even after adjusting for individual-level SES. Little is known about the physical manifestation of neighbourhood SES that may underlie this relationship. Several studies have found that lower-SES neighbourhoods have fewer PA resources available, potentially contributing to lower rates of PA. Women may be particularly vulnerable to neighbourhood influences on health, but there are few data available to help understand these phenomena. This study investigated whether the availability of PA resources mediated the relationship between neighbourhood SES and PA among women.

Although we found expected relationships between residence in a lower-SES neighbourhood and less moderate or vigorous PA among women, we also found that these same women reported greater overall energy expenditure, perhaps as a result of greater work or travel demands. The relationship between neighbourhood SES and PA is complex; greater availability of PA resources nearby appears to differentially benefit women living in lower-SES neighbourhoods and low-income women, having implications for policy-making and planning. Future work should investigate the qualitative features of PA resources that enhance PA opportunities, and more work is needed to understand the lower rates of PA in women across the SES spectrum.

Policy implications

Having access to physical activity (PA) resources may provide benefits for women in low-socioeconomic status (SES) neighbourhoods and low-income women. Policies that favour municipal improvements in lower-SES neighbourhoods that focus on increasing access to and improvement and maintenance of PA resources may have important benefits for resident PA.

proportions of missing data. Given the variability in the accuracy of geocodes,[42] our study was strengthened by validating the accuracy of the geocodes. The survey data and participant addresses available for geocoding were virtually complete. The opportunity to apply complex statistical modelling methodology and investigation of cross-level interactions provides fresh insight into the veracity and complexity of the relationship between neighbourhood of residence and PA. Greater availability of PA resources nearby appears to differentially benefit women living in lower-SES neighbourhoods and low-income women. Neighbourhood SES and availability of resources are related to PA in women, and the field is ripe for future investigations that quantify this relationship further.

ACKNOWLEDGEMENTS

This work was co-funded by the National Institute of Environmental Health Sciences and the National Heart, Lung, and Blood Institute: grant R01 HL67731 to Dr Winkleby. The authors thank Ms Alana Koehler for her technical assistance in preparing the manuscript, and two anonymous reviewers for their helpful comments and suggestions.

Authors' affiliations

Rebecca E Lee, Health and Human Performance, University of Houston, Houston, TX, USA
Catherine Cubbin, Center on Social Disparities in Health, University of California, San Francisco, San Francisco, CA, USA; and Population Research Center, University of Texas at Austin, Austin, TX, USA
Marilyn Winkleby, Stanford Prevention Research Center, Stanford University School of Medicine, Stanford, California, USA

REFERENCES

1 **Yen IH**, Kaplan GA. Poverty area residence and changes in physical activity level: evidence from the Alameda County Study. *Am J Public Health* 1998;**88**:1709–12.
2 **Ross CE**. Walking, exercising, and smoking: does neighborhood matter? *Soc Sci Med* 2000;**51**(:265–74.
3 **US Department of Health and Human Services**. *Physical activity and health: a report of the Surgeon General*. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.
4 **Diez Roux AV**, Merkin SS, Arnett D, *et al*. Neighborhood of residence and incidence of coronary heart disease. *N Engl J Med* 2001;**345**:99–106.
5 **Lee RE**, Cubbin C. Neighborhood context and youth cardiovascular health behaviors. *Am J Public Health* 2002;**92**:428–36.
6 **Sundquist K**, Malmström M, Johansson S-E. Neighbourhood deprivation and incidence of coronary heart disease: a multilevel study of 2.6 million women and men in Sweden. *J Epidemiol Community Health* 2004;**58**:71–7.
7 **Winkleby MA**, Sundquist K, Cubbin C. Inequalities in CHD incidence and case fatality by neighborhood deprivation. *Am J Prev Med* 2007;**32**:97–106.
8 **Centers for Disease Control**. Prevalence of no leisure-time physical activity – 35 states and the District of Columbia, 1988–2002. *Morb Mortal Wkly Rep* 2003;**53**(4):82–6.
9 **Sampson RJ**, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science* 1997;**277**:918–24.
10 **Cubbin C**, Pickle LW, Fingerhut MA. Social context and geographic patterns of homicide among US Black and White males. *Am J Public Health* 2000;**90**:579–87.
11 **Ellaway A**, Macintyre S. Does where you live predict health related behaviours? A case study in Glasgow. *Health Bull* 1996;**54**:443–6.
12 **Morland K**, Wing S, Diez Roux A, *et al*. Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med* 2002;**22**:23–9.
13 **Macintyre S**. The social patterning of exercise behaviours: the role of personal and local resources. *Br J Sports Med* 2000;**34**(1):6.
14 **Estabrooks PA**, Lee RE, Gyurcsik NC. Resources for physical activity participation: does availability and accessibility differ by neighborhood socioeconomic status? *Ann Behav Med* 2003;**25**:100–4.
15 **Lee RE**, Reese-Smith J, Regan G, *et al*. Applying GIS technology to assess the obesogenic structure of neighborhoods surrounding public housing developments. *Med Sci Sports Exerc* 2003;**35S**.
16 **Giles-Corti B**, Broomhall MH, Knuiman M, *et al*. Increasing walking: how important is distance to, attractiveness, and size of public open space? *Am J Prev Med* 2005;**28**(Suppl. 2):169–76.
17 **Stafford M**, Cummins S, Macintyre S, *et al*. Gender differences in the associations between health and neighbourhood environment. *Soc Sci Med* 2005;**60**:1681–92.
18 **Putnam RD**. The strange disappearance of civic America. *Am Prospect* 1996;**7**(24):1–17.
19 **Carnegie MA**, Bauman A, Marshall AL, *et al*. Perceptions of the physical environment, stage of change for physical activity, and walking among Australian adults. *Res Q Exerc Sport* 2002;**73**:146–55.
20 **Centers for Disease Control**. Neighborhood safety and the prevalence of physical inactivity – selected states, 1996. *Morb Mortal Wkly Rep* 1999;**53**(4):143–6.
21 **Sallis JF**, Johnson MF, Calfas KJ, *et al*. Assessing perceived physical environmental variables that may influence physical activity. *Res Q Exerc Sport* 1997;**68**:345–51.
22 **Stahl T**, Rutten A, Nutbeam D, *et al*. The importance of the social environment for physically active lifestyle-results from an international study. *Soc Sci Med* 2001;**52**:1–10.
23 **Sternfeld B**, Ainsworth BE, Quesenberry CP. Physical activity patterns in a diverse population of women. *Prev Med* 1999;**28**:313–23.
24 **Booth SL**, Sallis JF, Ritenbaugh C, *et al*. Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. *Nutr Rev*. 2001;59: S21–39; discussion S57–65, (3 Pt 2).
25 **Huston SL**, Evenson KR, Bors P, *et al*. Neighborhood environment, access to places for activity, and leisure-time physical activity in a diverse North Carolina population. *Am J Health Promot* 2003;**18**:58–69.
26 **Troped PJ**, Saunders RP, Pate RR, *et al*. Associations between self-reported and objective physical environmental factors and use of a community rail-trail. *Prev Med* 2001;**32**:191–200.
27 **Ellaway A**, Macintyre S. Women in their place: gender and perceptions of neighbourhoods and health in the West of Scotland. In: Dyck I, Davis Lewis N, McLafferty S, eds. *Geographies of women's health*. London: Routledge, 2001:336.
28 **Echeverria SE**, Diez-Roux AV, Link BG. Reliability of self-reported neighborhood characteristics. *J Urban Health* 2004;**81**:682–701.
29 **Lee RE**, Castro CM, Albright CL, *et al*. Neighborhood perceptions among low-income, ethnic minority women: Are active women more accurate? 2002(24S)..
30 **Kirtland KA**, Porter DE, Addy CL, *et al*. Environmental measures of physical activity supports: perception versus reality. *Am J Prev Med* 2003;**24**:323–31.
31 **Sallis JF**, Hovell MF, Hofstetter CR, *et al*. Distance between homes and exercise facilities related to frequency of exercise among San Diego residents. *Public Health Rep* 1990;**105**:179–85.
32 **Bauman A**, Smith B, Stoker L, *et al*. Geographical influences upon physical activity participation: evidence of a 'coastal effect'. *Aust N Z J Public Health* 1999;**23**:322–4.
33 **Farquhar JW**, Fortmann SP, Maccoby N, *et al*. The Stanford Five-City Project: design and methods. *Am J Epidemiol* 1985;**122**:323–34.
34 **Fortmann SP**, Marcuson R, Bitter PH, *et al*. A comparison of the Sphygmetrics SR-2 automatic blood pressure recorder to the mercury sphygmomanometer in population studies. *Am J Epidemiol* 1981;**114**:836–44.
35 **Fortmann SP**, Rogers T, Haskell WL, *et al*. Indirect measures of cigarette use: expired air carbon monoxide vs. plasma thiocyanate. *Prev Med* 1984;**13**:127–34.
36 **Farquhar JW**, Fortmann SP, Flora JA, *et al*. Effects of communitywide education on cardiovascular disease risk factors: the Stanford Five-City Project. *JAMA* 1990;**264**:359–65.
37 **Fortmann SP**, Winkleby MA, Flora JA, *et al*. Effect of long-term community health education on blood pressure and hypertension control: the Stanford Five-City Project. *Am J Epidemiol* 1990;**132**:629–46.
38 **Winkleby MA**, Feldman HA, Murray DM. Joint analysis of three U.S. community intervention trials for reduction of cardiovascular disease risk. *J Clin Epidemiol* 1997;**50**:645–58.
39 **Cubbin C**, Hadden WC, Winkleby MA. Neighborhood context and cardiovascular disease risk factors: the contribution of material deprivation. *Ethnicity Dis* 2001;**11**:687–700.
40 **LeClere FB**, Rogers RG, Peters K. Neighborhood social context and racial differences in women's heart disease mortality. *J Health Soc Behav* 1998;**39**:91–107.
41 **Winkleby MA**, Cubbin C. Influence of individual and neighbourhood socioeconomic status on mortality among black, Mexican-American, and white women and men in the United States. *J Epidemiol Commun Health* 2003;**57**:444–52.
42 **Krieger N**, Waterman P, Lemieux K, *et al*. On the wrong side of the tracts? Evaluating the accuracy of geocoding in public health research. *Am J Public Health* 2001;**91**(7):1114–6.
43 **Lee RE**, Booth KM, Reese-Smith JY, *et al*. The Physical Activity Resource Assessment (PARA) instrument: evaluating features, amenities and incivilities of physical activity resources in urban neighborhoods. *Int J Behav Nutr Phys Act* 2005;**2**:13–22.
44 **Young DR**, Haskell WL, Taylor CB, *et al*. Effect of community health education on physical activity knowledge, attitudes, and behavior. The Stanford Five-City Project. *Am J Epidemiol* 1996;**144**:264–74.
45 **Sallis JF**, Haskell WL, Wood PD, *et al*. Physical activity assessment methodology in the Five-City Project. *Am J Epidemiol* 1985;**121**:91–106.
46 **Blair SN**, Haskell WL, Ho P, *et al*. Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments. *Am J Epidemiol* 1985;**122**:794–804.
47 **SAS Institute Inc**. *SAS/STAT User's Guide*, Version 8, Vol. 1. Cary, NC: SAS Institute Inc, 1999.
48 **Regan G**, Lee RE, Booth K, *et al*. Obesogenic influences in public housing: a mixed-method analysis. *Am J Health Promot* 2006;**20**:282–90.
49 **Saelens BE**, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. *Ann Behav Med* 2003;**25**:80–91.

50 **Powell LM**, Slater S, Chaloupka FJ, *et al*. Availability of physical activity-related facilities and neighborhood demographic and socioeconomic characteristics: a national study. *Am J Public Health* 2006;**96**:1676–80.
51 **King WC**, Brach JS, Belle S, *et al*. The relationship between convenience of destinations and walking levels in older women. *Am J Health Promot* 2003;**18**:74–82.
52 **Powell KE**, Martin LM, Chowdhury PP. Places to walk: convenience and regular physical activity. *Am J Public Health* 2003;**93**:1519–21.
53 **Cubbin C**, Sundquist K, Ahlén H, *et al*. Neighborhood deprivation and cardiovascular disease risk factors: protective and harmful effects. *Scand J Public Health* 2006;**34**:228–37.
54 **Coen SE**, Ross NA. Exploring the material basis for health: characteristics of parks in Montreal neighborhoods with contrasting health outcomes. *Health Place* 2006;**12**:361–71.
55 **Blakely TA**, Woodward AJ. Ecological effects in multi-level studies. *J Epidemiol Community Health* 2000;**54**:367–74.

SPEAKERS' CORNER

King Saul, work-related stress and depression

Martijn Huisman

The story of King Saul in the Bible provides a good example of a man suffering from depression, and I believe that the story fits well with current scientific understanding of the role of work-related stress as a determinant of depression.[1 2]

According to Karasek's job stress model, a combination of high demands and low control at work will lead to psychological stress,[3] which can eventually lead to chronic disease, including psychopathology. Several elements in the story of King Saul are illustrative of the effects of job-related stress. I will relate just one episode that I found especially moving when I read it.

This context is Saul's war against the Philistines. From the start it is quite clear that Saul faces extremely unfavourable odds. His people panic when the Philistine army gathers before them, which is not surprising, as Saul's core army amounts to about 3000 men, while the Philistine army consists of ''thirty thousand chariots, and six thousand horsemen, and people as the sand which is on the seashore in multitude'' (1 Samuel 13.5). Furthermore, Saul has been ordered by the religious leader Samuel to wait for his arrival after the hostilities have started, so that Samuel will make it known what Saul must do. Samuel, as Israel's religious leader, speaks for God. Ignoring his order is out of the question.

Clearly, the demands are extremely high: fighting a war against all odds, keeping his frightened soldiers under control and facing what appears to be almost certain defeat. Saul's control over the situation is obviously minimal. Before he can actually take action, Saul needs to wait for the arrival of Samuel (for 7 days!) so that he can be told what course of action to follow.

In the end, Saul cannot bear the stress and he does what is forbidden to him. He starts by giving burnt offerings to God, in order to gain his favour in battle. However, giving burnt offerings was traditionally a domain preserved for the priests and hence was forbidden to the king. When Samuel finally arrives, he reprimand Saul severely. Samuel says: ''thou hast done foolishly: thou hast not kept the commandment of the Lord thy God, which he commanded thee: […] now thy kingdom shall not continue […]'' (1 Samuel 13.13–14).

Subsequently, Saul begins to display the well-known signs of depression.

It is through an emotional experience of a piece of literature that we learn from it.[4] I believe that the story of King Saul in the Bible can provide us with such an experience, which can help us understand the links between environmental stress and mental illness.

Martijn Huisman

Correspondence to: Department of Psychiatry, University Medical Center Groningen, PO Box 30001, 9700 AD Groningen, The Netherlands; martijn.huisman@med.umcg.nl

Funding: None

Conflict of interest: None.

doi: 10.1136/jech.2007.066522

References

1 **Niedhammer I**, Goldberg M, Leclerc A, *et al*. Psychosocial factors at work and subsequent depressive symptoms in the Gazel cohort. *Scand J Work Environ Health* 1998;**24**:197–205.
2 **Wang J**. Work stress as a risk factor for major depressive episode(s). *Psychol Med* 2005;**35**:865–71.
3 **Karasek R**. Job demands, job decision latitude and mental strain: implications for job redesign. *Adm Sci Quart* 1979;**24**:285–306.
4 **Robinson J**. *Deeper than reason; emotion and its role in literature, music, and art*. Oxford: Oxford University Press, 2005.